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Non-LTE models for neutron star atmospheres and supernova-fallback disks

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Abstract

We describe our recent progress in modeling supernova-fallback disks and neutron star (NS) atmospheres. We present a first detailed spectrum synthesis calculation of a SN-fallback disk composed of iron. We assume a thin disk with a radial structure described by the α-disk model. The vertical structure and emission spectrum are computed self-consistently by solving the structure equations simultaneously with the radiation transfer equations under non-LTE conditions. We describe the properties of a specific disk model and discuss various effects on the emergent UV/optical spectrum. We investigate Compton scattering effects on the thermal spectrum of NSs. In addition, we constructed a new generation of metal line-blanketed non-LTE model atmospheres for NSs. It is compared to X-ray burst spectra of EXO 0748–676. It is possible that the gravitational redshift, deduced from absorption lines, is lower ($z = 0.24$) than hitherto assumed ($z = 0.35$). Accordingly, this would result in NS mass and radius lower limits of $M \geqslant 1.63\ M_\odot$ and $R \geqslant 13.8$ km.

Keywords: Neutron stars; Infall; Accretion; Accretion disks

1. Introduction

We report on our recent progress in radiation transfer modeling for supernova-fallback disks and non-magnetic neutron star (NS) atmospheres. Disk modeling is described in Section 2. We then present effects of Compton scattering on the thermal spectra of NS atmospheres (Section 3). In Section 4, we describe the construction of new line-blanketed NLTE atmosphere models for NSs. These models are applied to X-ray burst spectra of EXO 0748–676 (Section 5).

2. NLTE models for SN fallback disks

Anomalous X-ray pulsars (AXPs) are slowly rotating young isolated NSs. Their X-ray luminosities greatly exceed the rates of rotational energy loss. It is now generally believed that AXPs are magnetars and that their X-ray luminosity is powered by magnetic energy. As an alternative explanation the X-ray emission was attributed to accretion from a disk that is made up of supernova-fallback material (e.g. van Paradijs et al., 1995). It is still a matter of debate whether the disk model is appropriate. For example, the discovery of optical pulsations in 4U 0142 + 61 with the same period like the X-ray pulsations (Kern and Martin, 2002) appears to be a strong argument against the disk model. It was argued that reprocessing of the pulsed NS X-ray emission in the disk cannot explain the high optical pulsed fraction, because disk radiation would be dominated by viscous dissipation and not by reprocessed NS irradiation (Kern and Martin, 2002). In contrast, Ertan and Cheng (2004) showed that the optical pulsations can be explained either by the magnetar outer gap model or by the disk-star dynamo model. A spectral break in the optical spectrum of 4U 0142 + 61 was discovered by Hulleman et al. (2004) and also taken as an argument against the disk model. The recent discovery of

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